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MEMORANDUM FOR IN-HOUSE PUBLICATIONS

FROM: PROI (TI) (STINFO)

10 Jul 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-113
C.W. Beckman, R.L. Geisler "The History of the BATES Motor at RPL

AIAA slides

(Statement A)

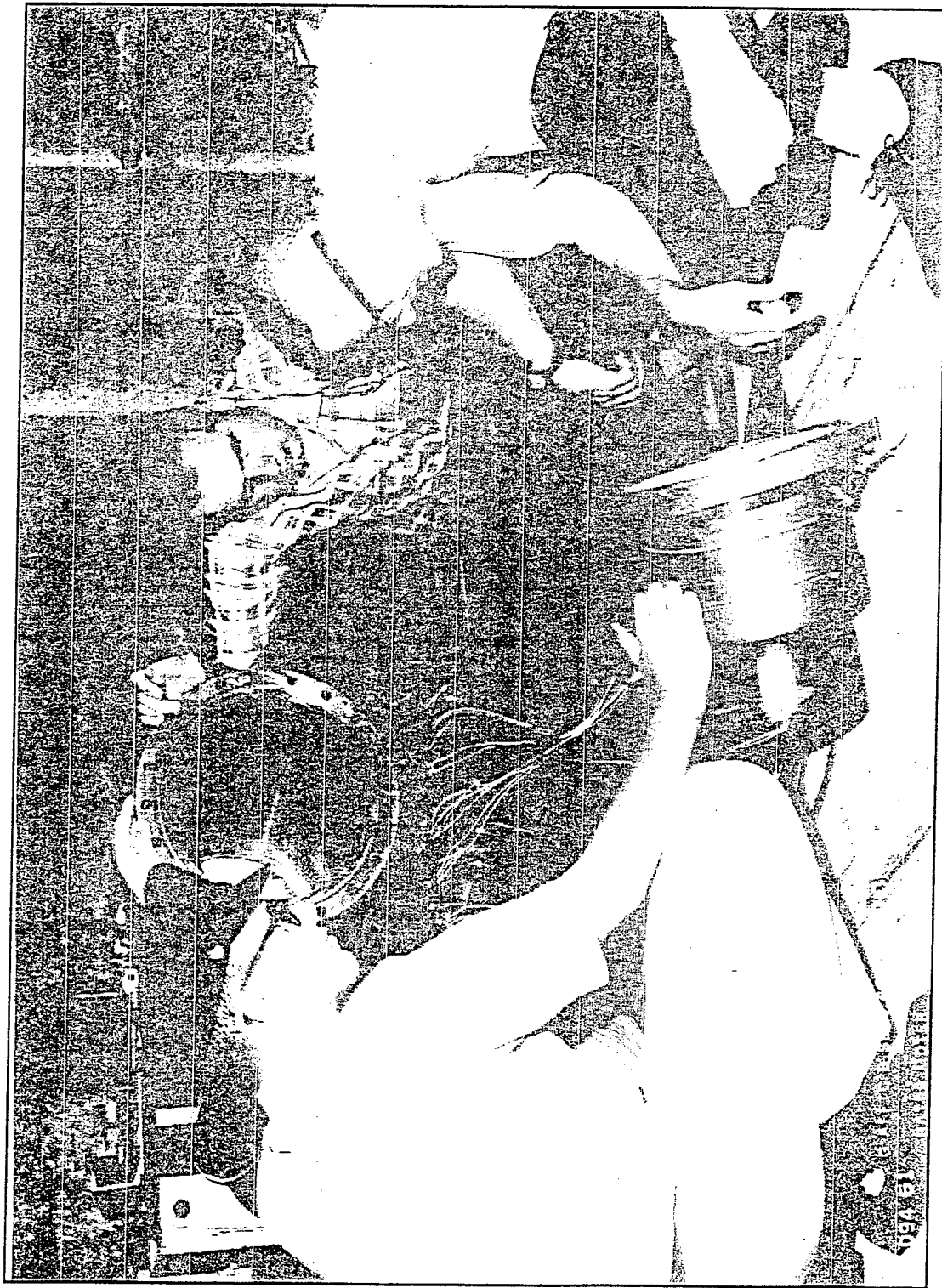


THE HISTORY OF THE BATES MOTOR AT RPL

CHARLES W. BECKMAN
AIR FORCE RESEARCH LABORATORY
ROBERT L. GEISLER
GEISLER ENTERPRISES



INITIAL BATES FIRING - Sept 1961





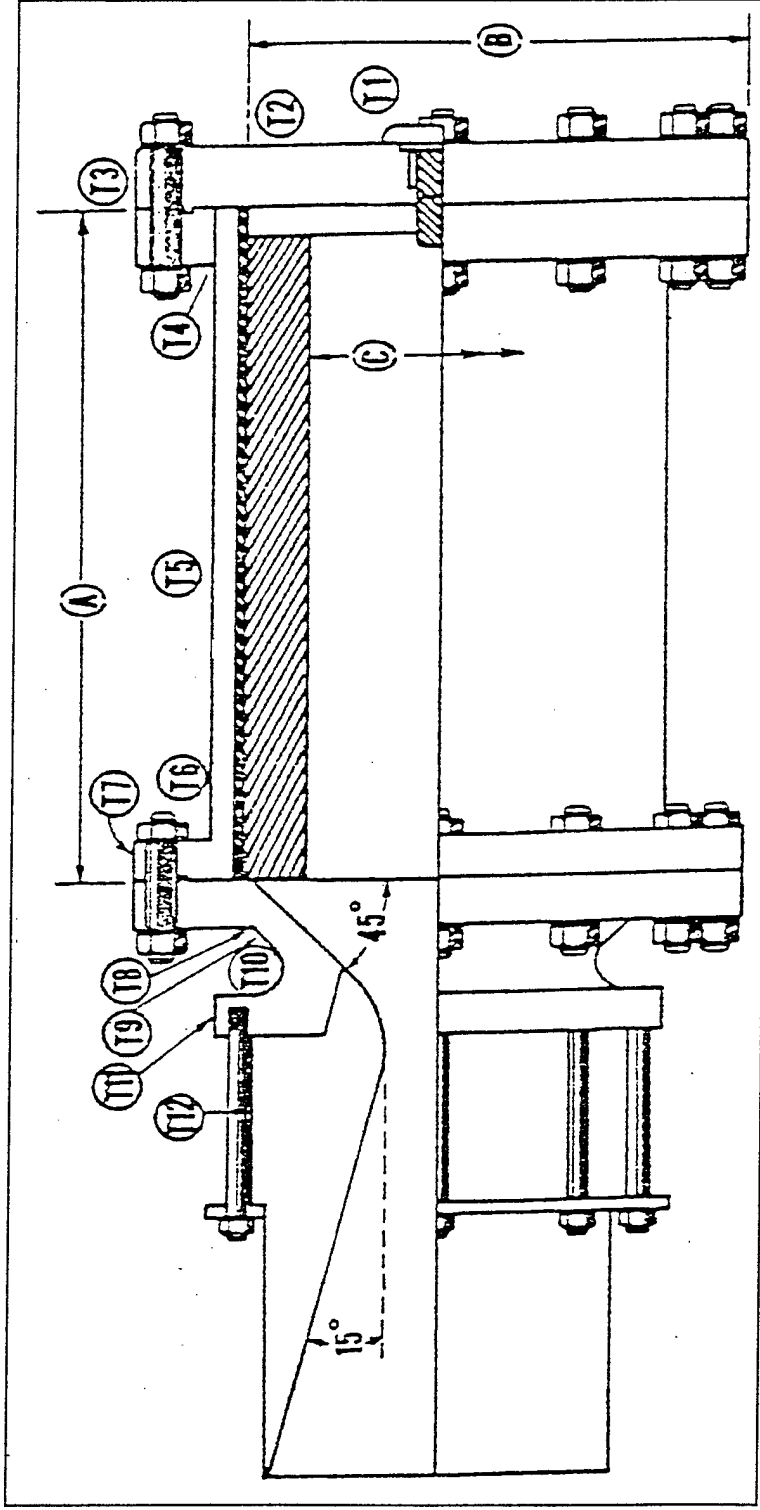
BATES

Ballistic Test Evaluation and Scaling

A highly accurate test motor system for ballistic prediction, assessment and comparison.



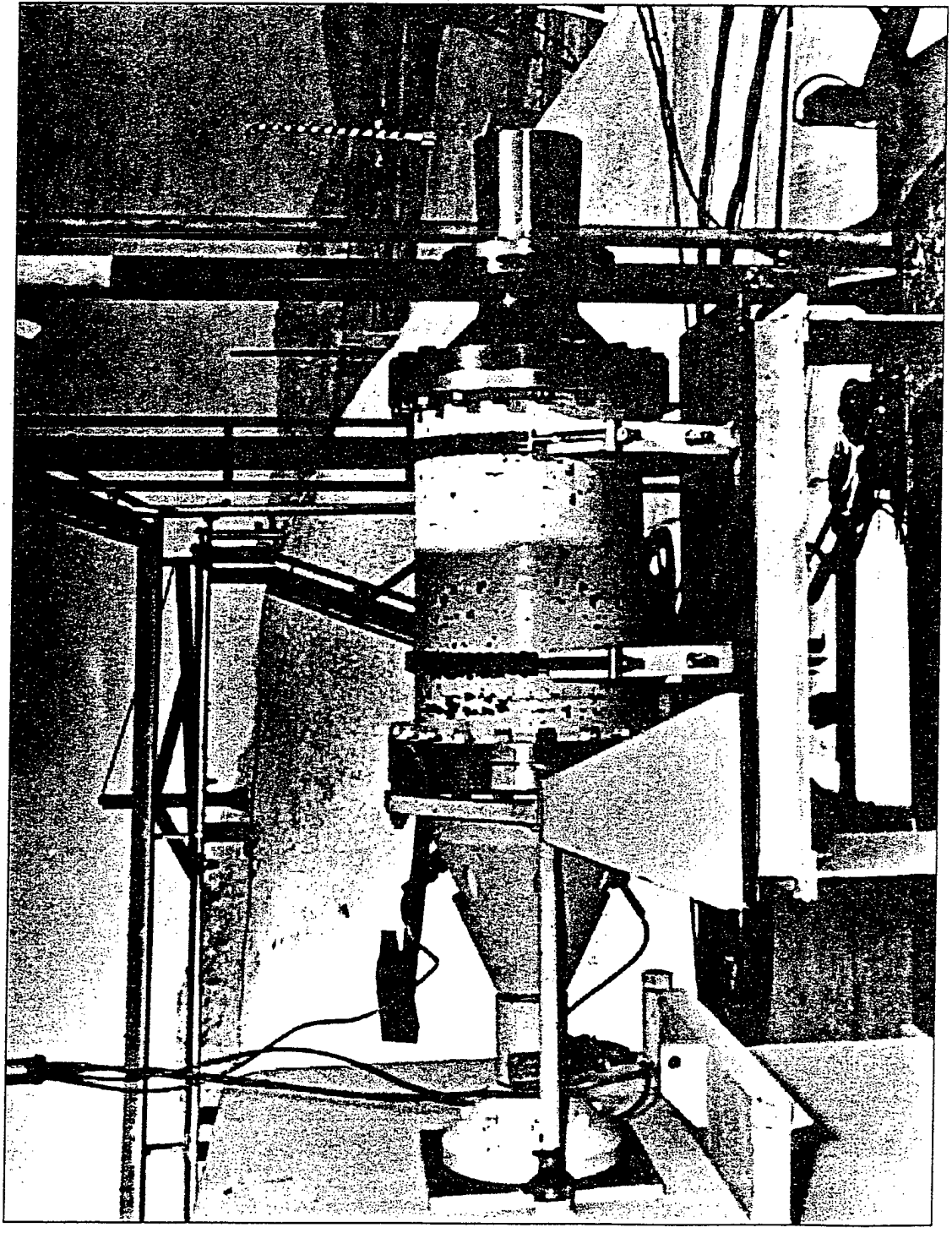
15-lb and 70-lb BATES Motor Design



Motor size	15-pound	70-pound
Pressure (psi)	1000.	1000.
Nozzle Diameter ^{units}	1.	2.
Gas Residence Time (msec)	8.	17.
Grain Length (in) (A)	12.	20.
Grain Outside Diameter (in) (B)	6.75	12.
Grain Port Diameter (in) (C)	4.6	8.



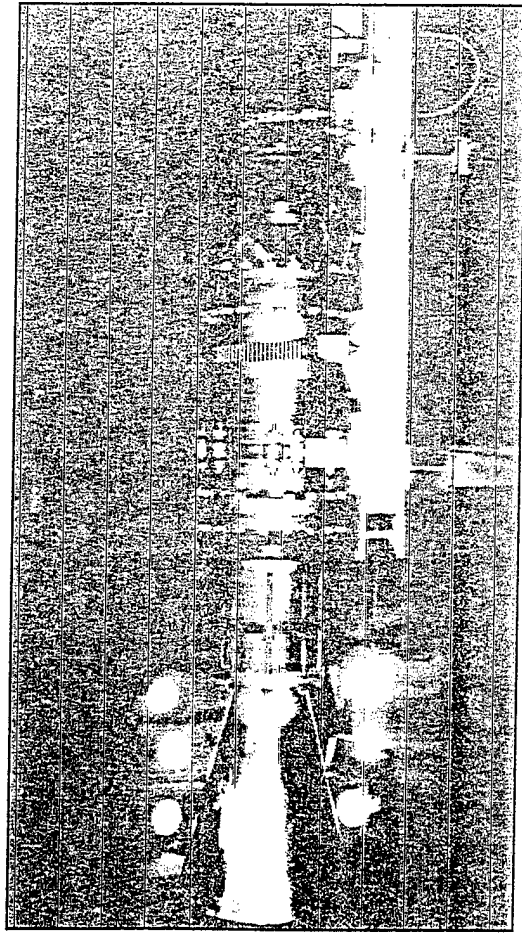
Standard 70-lb BATES Motor



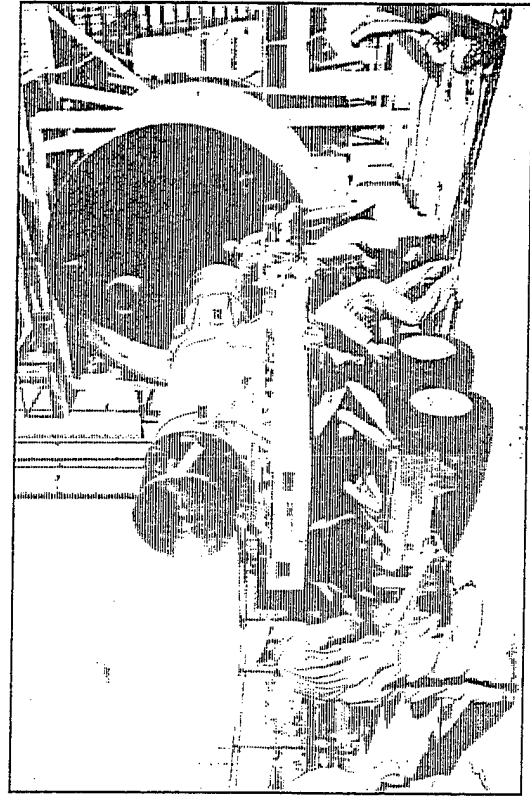


Vacuum Ballistics Testing

ama1 ppt



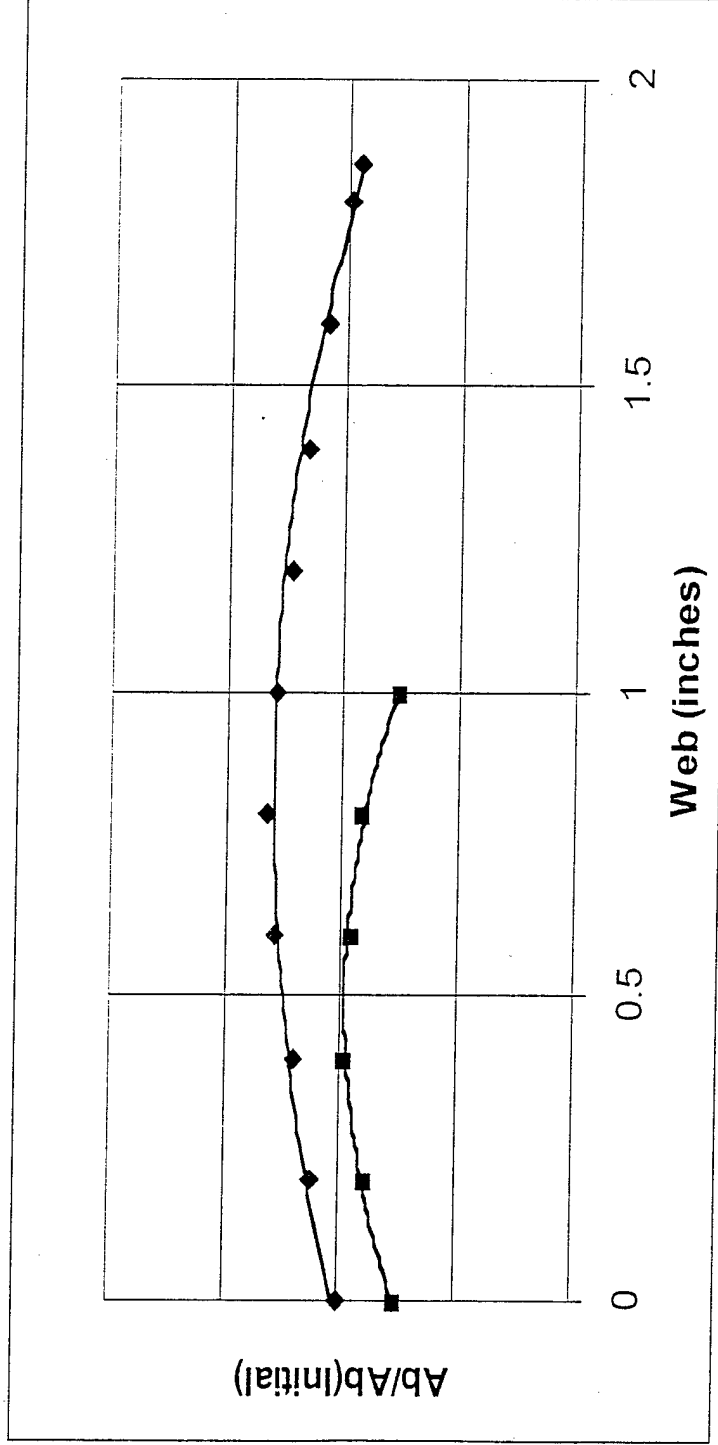
70 Pound Reusable
BATES Motor



Super BATES Reusable
Motor



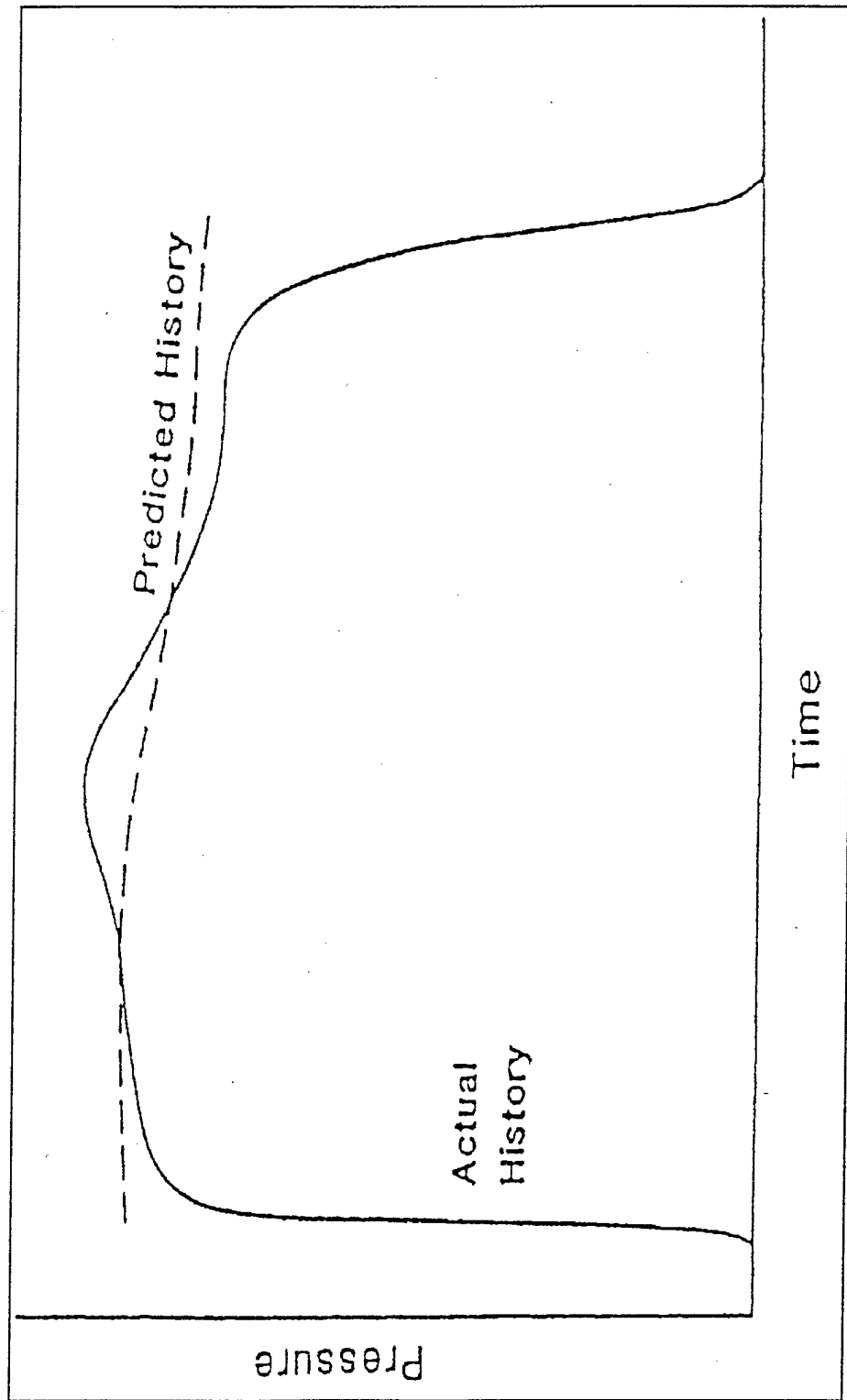
15-lb and 70-lb BATES Burnback History



Motor size 15-pound/70-pound
Neutrality (max/ave/min) 1.01/1.00/0.97
Port/Throat Ratio ~30



Ballistic Anomaly Phenomena





BATES DELIVERED SPECIFIC IMPULSE

ESTIMATED ERROR

+ 0.25 seconds

70-pound thrust accuracy + 0.10 %

15-pound thrust accuracy + 0.25 %

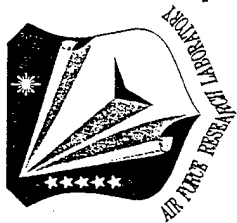
3 70-pound firings required for this precision

6 15-pound firings required for this precision

+ 0.10 seconds

6 70-pound firings required for this precision

9 15-pound firings required for this precision



BATES Test History

Motor Firings

Approximately 4000 test firings

Propellant Evaluations

Approximately 400 formulations evaluated

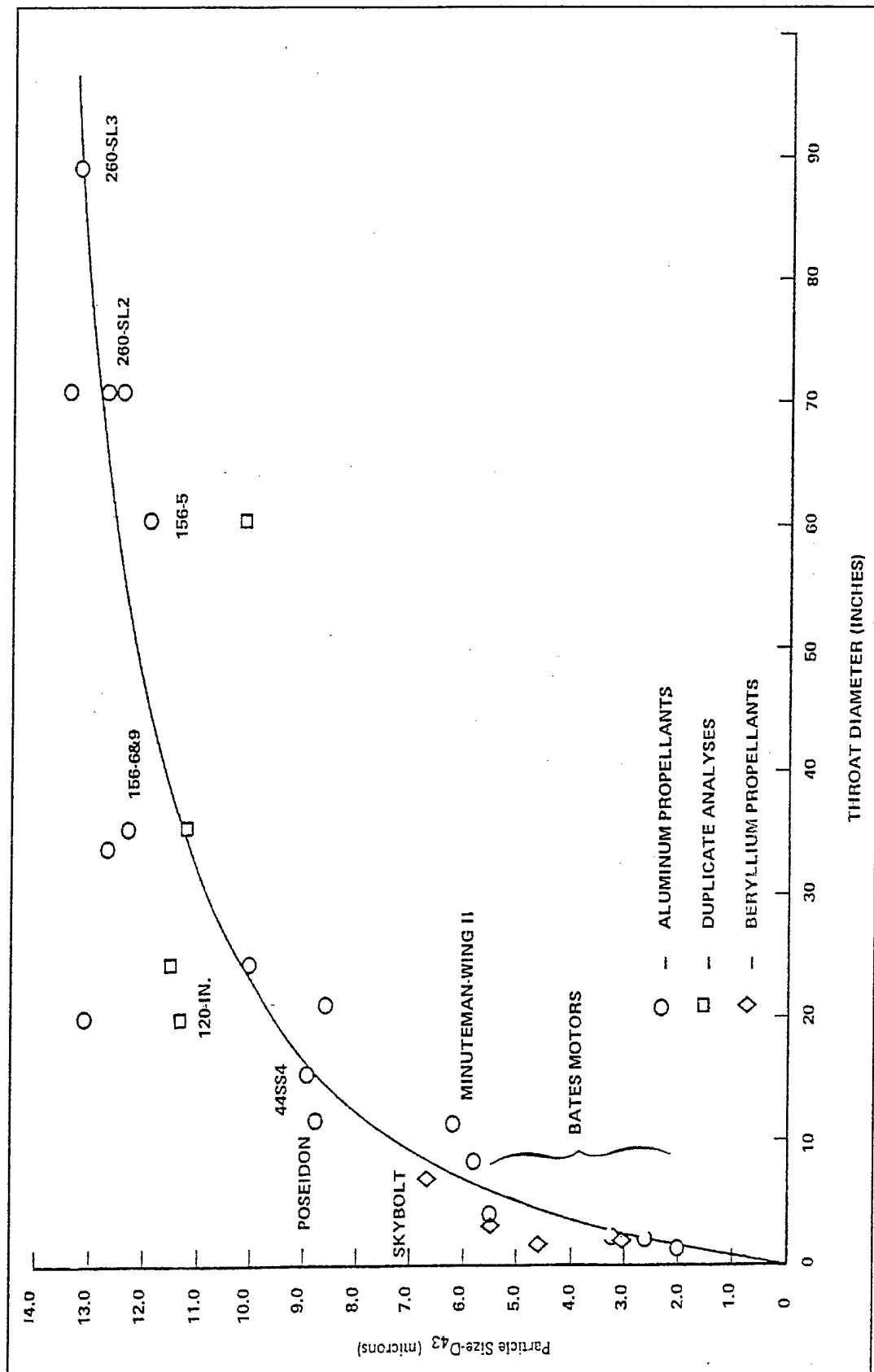


SPECIFIC IMPULSE EFFICIENCY INFLUENCES

- **COMBUSTION EFFICIENCY**
- **HEAT LOSS**
- **DIVERGENCE LOSSES**
- **TWO-PHASE FLOW LOSSES**
 - **MULTIPHASE MOMENTUM LOSSES**
 - **MULTIPHASE TEMPERATURE NON-EQUILIBRIUM**
- **CHEMICAL RECOMBINATION LOSSES**
- **FRICTIONAL LOSSES**

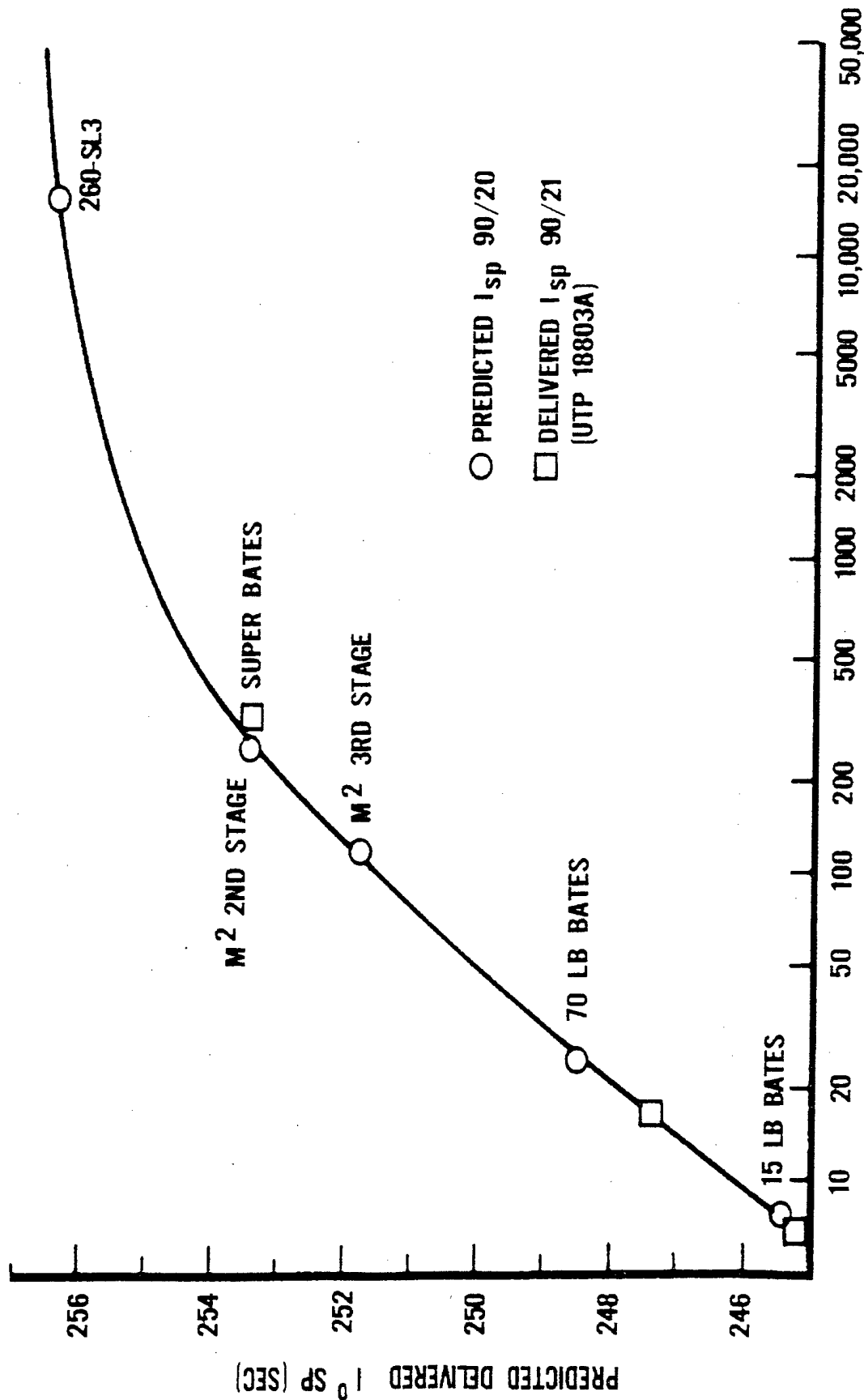


Particle Size vs Throat Diameter





Delivered Isp vs Mass Flow Rate





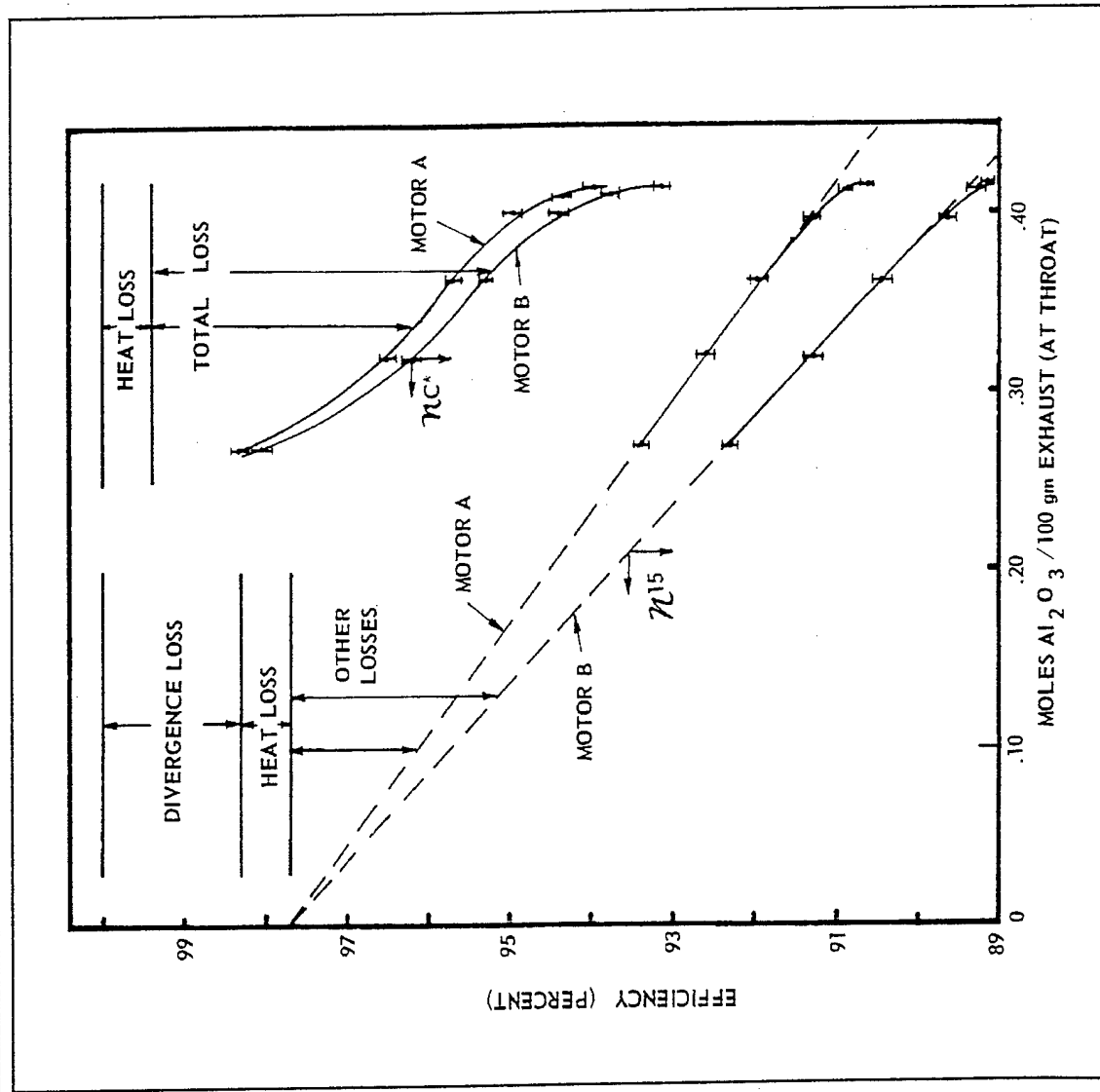
Varying Aluminum Propellant Formulations

alaa1.ppt

Wt% Al	15.	18.	21.	24.	27.	30.
Wt% AP	75.	72.	69.	66.	63.	60.
Wt% HTPB	10.	10.	10.	10.	10.	10.
Rb 1000 psia	0.56	0.55	0.56	0.46	0.51	0.50
η^{15} (ISP)15-lb	92.30	91.27	90.48	89.59	89.11	88.89
η^{15} (ISP)70-lb	93.38	92.84	92.03	91.31	90.92	90.51
Tc(K)@1000psi	3602.	3682.	3746.	3784.	3787.	3743.
T*(K) no Al	2859.	2791.	2705.	2605.	2494.	2376.
Moles/100 gm.	0.269	0.319	0.362	0.396	0.413	0.415
Al ₂ O ₃ at Thrt						



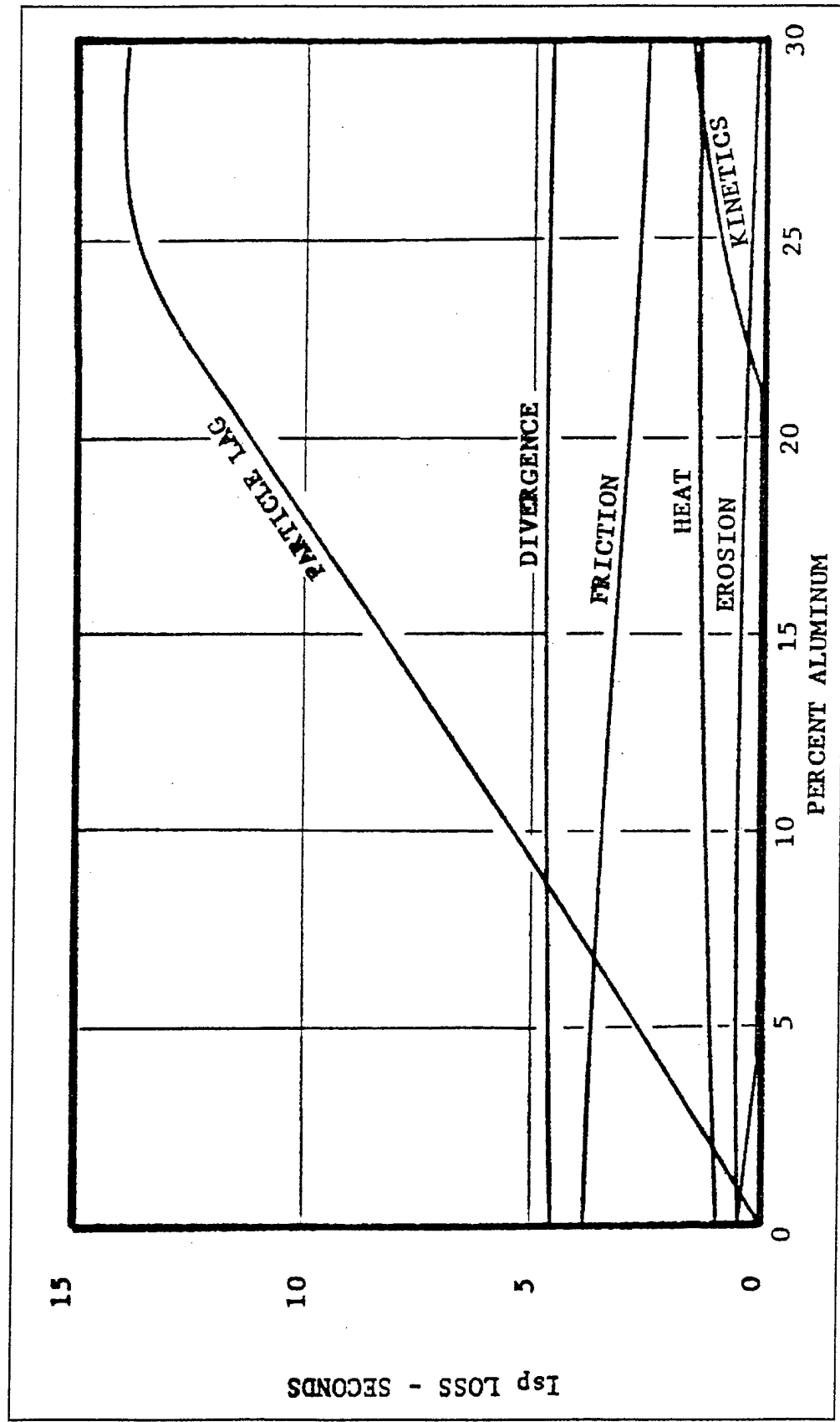
Initial BATES Scaling Approach





Thrust Losses Occurring in the 70-lb BATES Motor

china 1.ppt



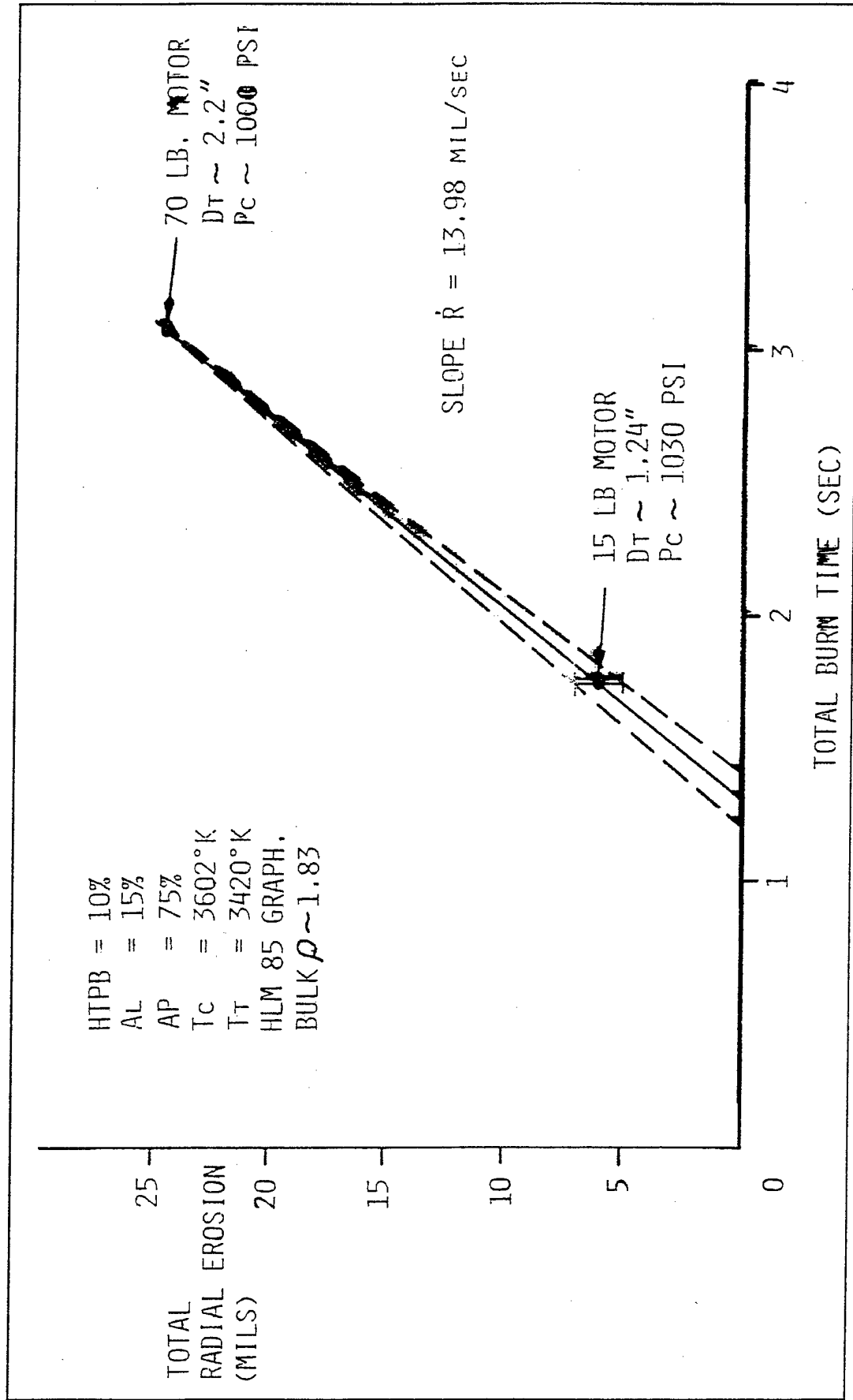


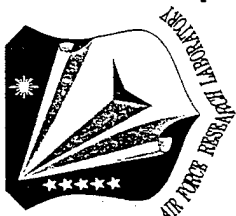
BATES Laser Particle Size Measurements



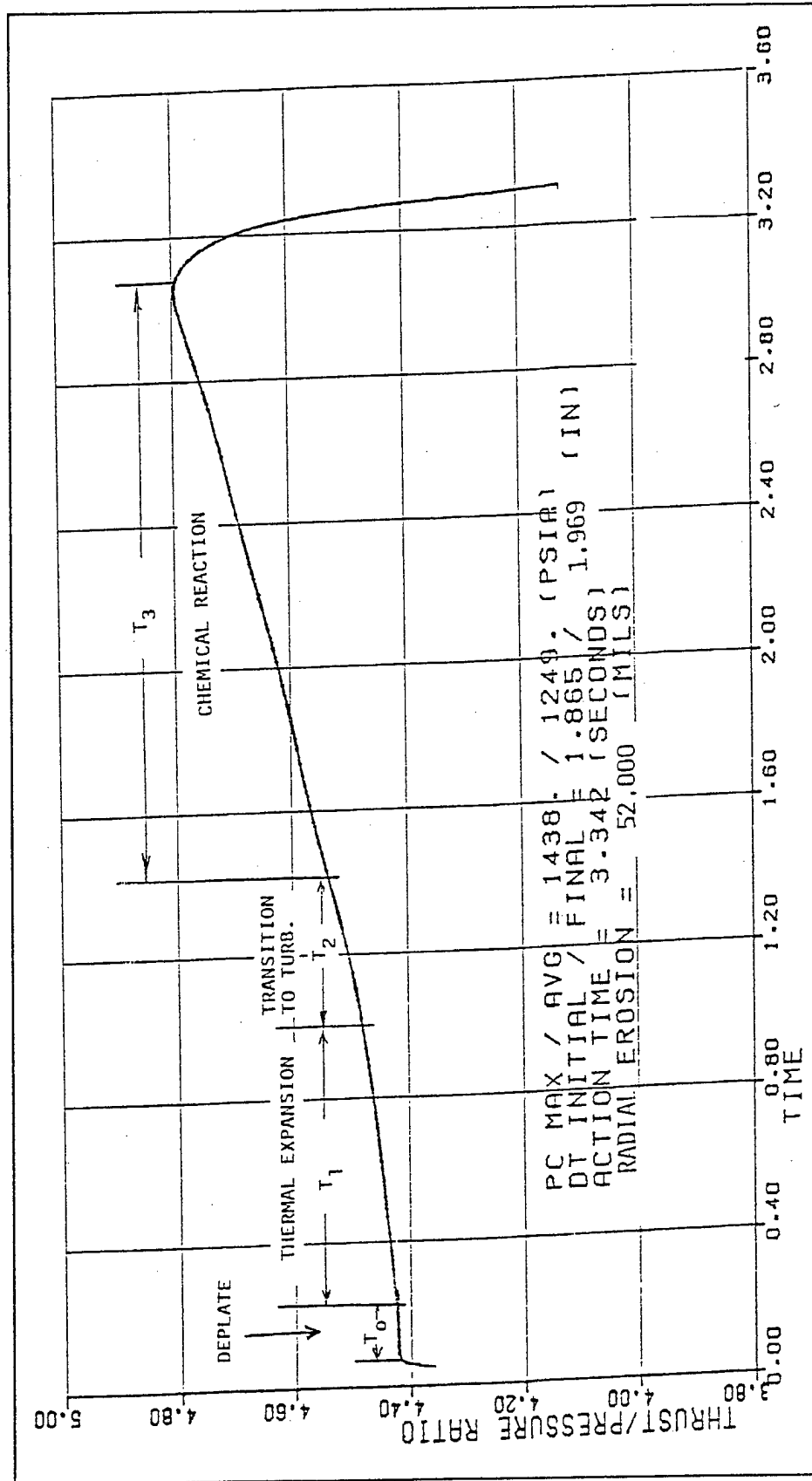


Initial Recession Analysis





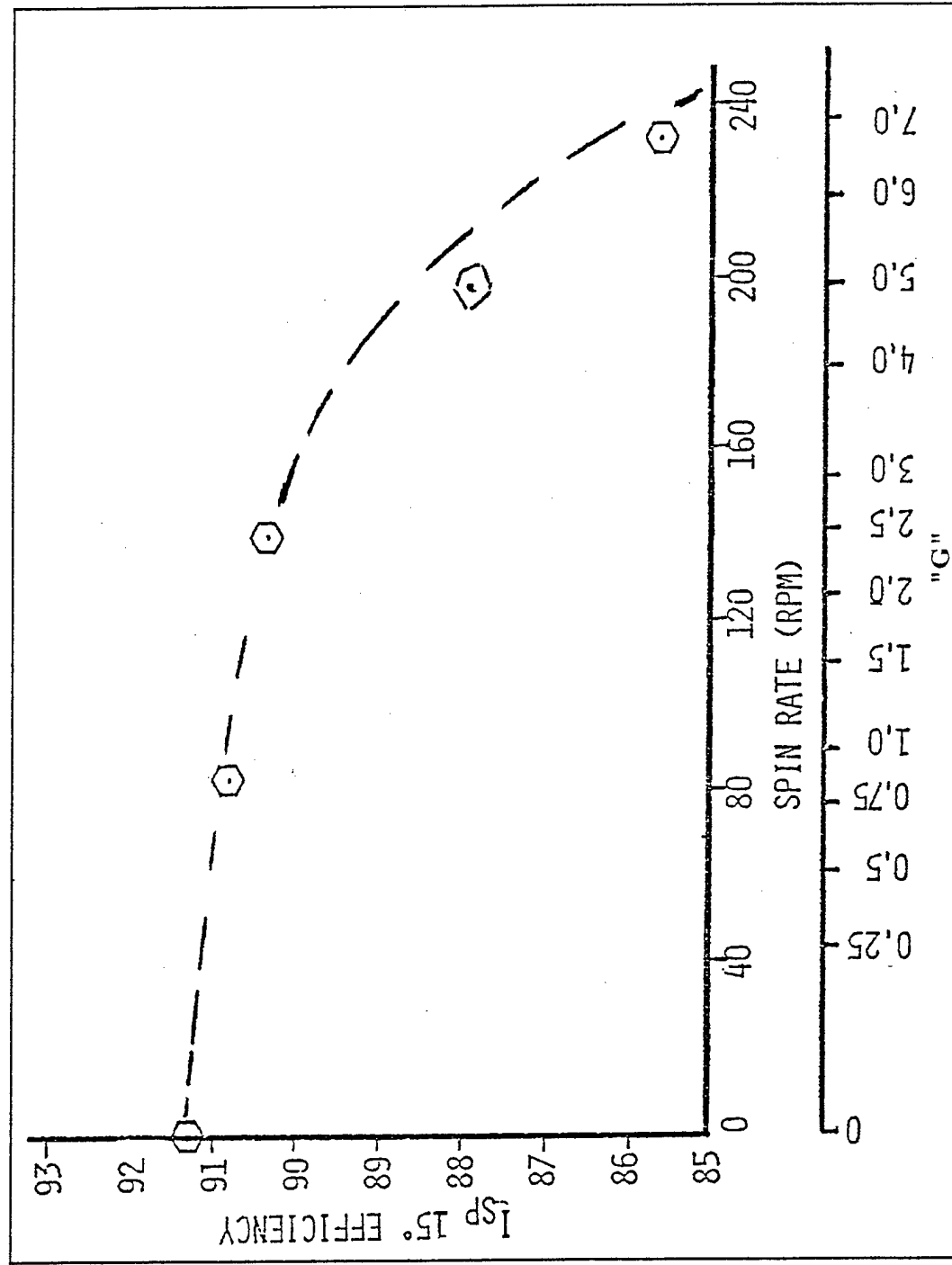
Thrust/Pressure Analysis





Isp Efficiency Vs Spin "G" Level (70 lb BATES)

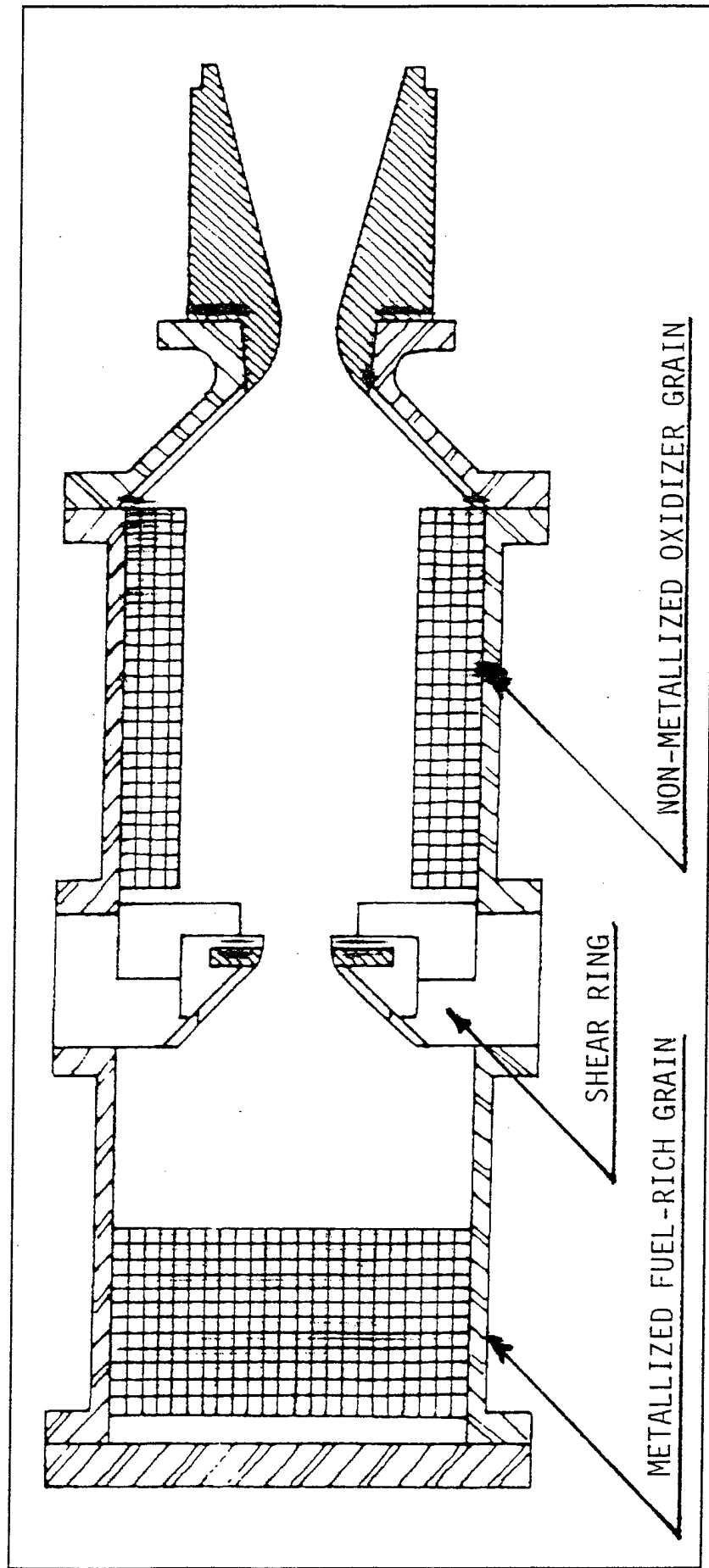
slaa 1 ppt





Dual Chamber Staged Combustion Feasibility Motor

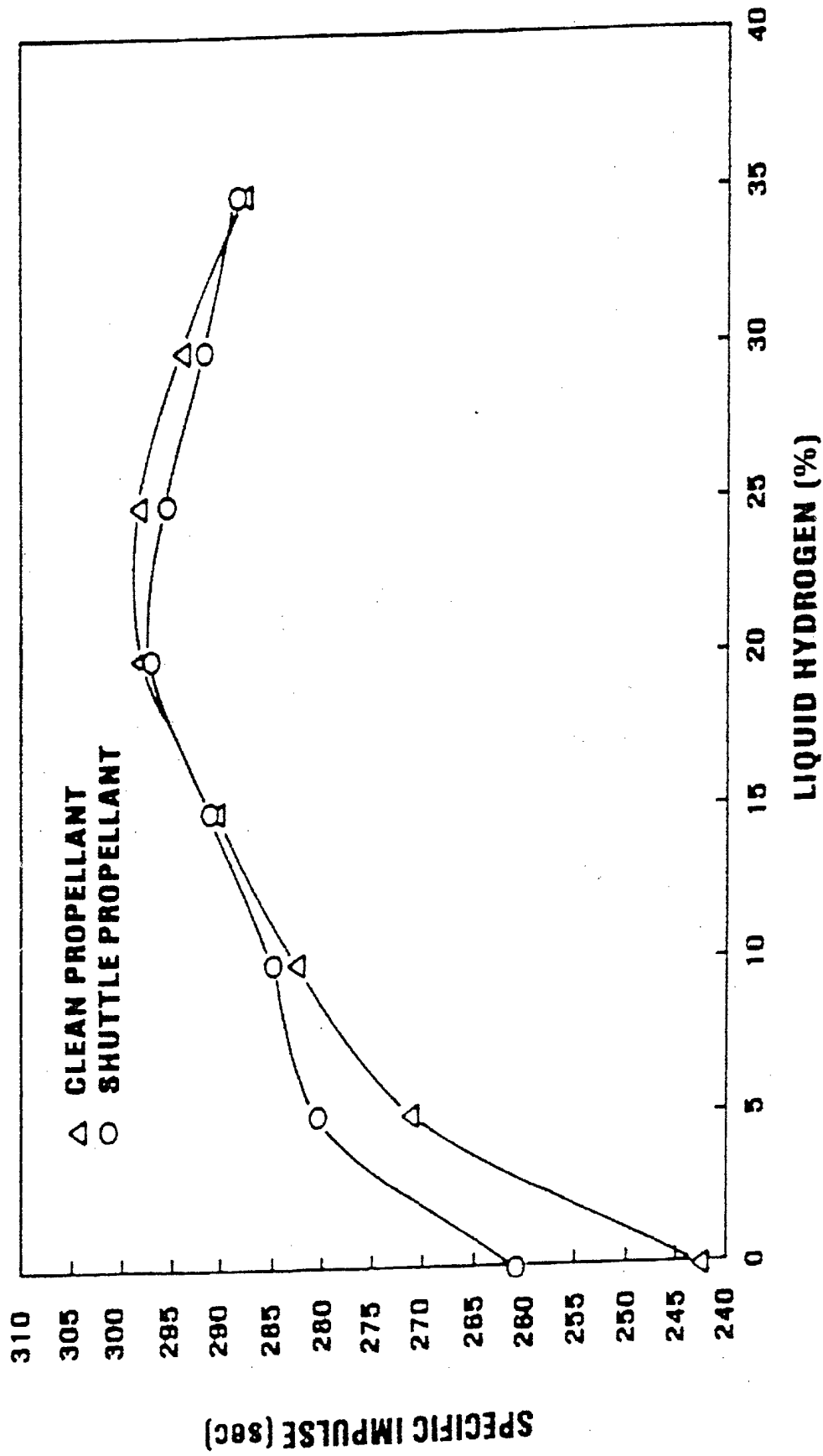
nlac1 ppt





Performance Increase from Hydrogen Augmentation

PERFORMANCE INCREASE OF SOLID MOTORS





Summary

- **BATES is an Invaluable Assessment Tool**
 - Provides Precision Measurements
 - Simple and Analyzable Hardware
 - Adaptable to Tactical, Strategic or Space Needs
- Irreplaceable Propellant and Ballistic Database**